COMPARATIVE STUDY OF WEED CONTROL METHODS IN RICE

by

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Weeds copmpete with rice for light, nutrients, water, and space. They reduce yields and lower the market value of the crop by reducing its quality, if they are not controlled adequately. The annual losses to the rice crop from competition with weeds are estimated to amount 23 percent of the total farm value of the rice crop or 73 million dollars in the United States.

Methods of weed control have been roughly classified into three groups, namely: (1) ecological control method; (2) mechanical control method, and (3) chemical control method (Matsubayashi, 1963). In Taiwan, hand weeding has been the traditional and standard method of weed control. In recent years, however, interest in chemical weed control has intensified with the introduction of new herbicides on the market and some of them have already been evaluated for control of weeds in rice (Chang, 1961; Young, 1962). The use of herbicides already has gained wide acceptance among farmers in the United States and Japan since the herbicide, 24-D, was first used for selective weed control in early 1944 (Price and Klingman, 1958). Surveys indicated that in 1959 farmers used more than 100 million pounds of herbicides on approximately 50 million acres of agricultural land at an estimated cost of 150 million dollars in the United States (Shaw and Danielson, 1961). Smith *et al.* (1959) reported that 40-60% of United States rice crop is being sprayed each year with 2, 4-D, MCPA or closely related herbicides.

In wet season, 1964 the International Rice Research Institute initiated a research program to evaluate new chemicals and chemical combinations for weed control in rice at Chiayi, Taiwan and other rice growing tropical countries, in cooperation with Chiayi Agricultural Experiment Station and other Asian Rice Research Institutions. The purpose of this paper is to present a brief summary of the significant results obtained at this Station.

MATERIALS AND METHODS

The experiment was conducted on the second crop (wet season) of 1964 at Chiayi Agricultural Experiment Station Farm, Chiayi, Taiwan. The paddy field is of clay loam soil with pH value, organic matter, and available phosphorus content ranging from 5.3 to 5.6, 1.60 to 1.75%, and 40 to 65 kilograms per hectare, respec-

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tively. Chianung 242, a leading commercial variety developed at this Staton, was used in this experiment.

A total of 15 treatments were arranged in randomized complete blocks with four replications. A 12 m^2 plot (3×4 m) was treated in each case and a 10 m^2 plot (2.5×4 m) was used as the unit for yield sampling. From each plot, two small subplots (20×50 cm) were randomly selected for weed counts and cover estimates. Levees were made arround the plots to prevent the interflow of herbicides between treatments.

Before transplanting, 1.50 kg per hectare of *Echinochloa* spp., 0.25 kg per hectare of *Monochoria vaginalis*, and 1.00 kg per hectare of *Fimbristylis* spp. and *Cyperus* spp. seeds were broadcast in order to insure a uniform and dense stand of weeds.

Herbicides were applied either by spraying or by broadcasting. The herbicides were sprayed by using a portable 1.5-liter hand sprayer. Approximately one liter of solution was sprayed for each plot to assure uniform and complete coverage of all plants. In case of dry applications, herbicides were thoroughly mixed with suitable amonnt of fine burned soils and broadcast evenly over a plot. The plots were drained before application of herbicides and they were flooded again one to two days after the application. The herbicides and rates of application are given in Table 1.

The experimental plots were transplanted in July 25, 1964 and harvested in November 4, 1964. The distance between rows was 25 cm and that between hills within a row was 20 cm. Approximately five seedlings were planted in each hill. The amount of fertilizer used was 80, 40, and 40 kg per hectare for N, P, and K respectively. All of P, K, and half of N were used as a basal dressing one day before transplanting and the balance of N used as a top-dressing at 20 days after transplanting. Insecticide, Sevin, was sprayed at 45, 65, and 80 days after transplanting for the control of rice stem borer. Fungicide, Tuzet, was sprayed at 80 days after transplanting to control sheath blight of rice. Special attention was paid to avoid applying insecticides within 10 days of herbicides treatment.

Weather conditions during the period of treatment were rather cloudy. Tropical shower visited almost every afternoon in August and in early September. Typhoon did not hit Taiwan directly, but they did bring heavy rains to the island. The climatic data for the period of herbicides treatment are presented in Table 2.

Data on weed counts, weed coverage, rice toxicity and dry weed weight were taken. Weed counts and weed coverage estimates were made twice, namely one day before treatment and 10 days after treatment based on the pre-set subplots. Weed control was graded three times, namely one day before, 10 days, and 40 days after treatment while rice toxicity was recorded 2 days, and 40 days after treatment, both grading were reported in percentage in comparison with weeded and non-weeded plots. Dry weed weight per plot was measured one week before harvesting.

Heading date, plant height, number of tillers, number of panicles, number of grains, panicle length, and 1,000-grain weight were recorded for each plot. Yield

Table 1. Herbicides used in tests

Treatment Code No.	Herbicides		Formulation Concentration	Active rate (kg/ha)	Time and method of application
	Common name	Chemical name			
1	PCP-Na	Pentachlorophenol	88% flake+soil	15	Sprayed 7.5 kg at 3 days+7.5 kg at 20 days after transplanting.
2	Propanil	3,4-dichloro-propionanilide	36% e.c.	3.5	Sprayed at 14 days after transplanting.
3	Propanil+MCPA	—	36+40% e.c.	3.5+0.8	Sprayed at 14 days after transplanting.
4	MCPA	2-methyl-4-chlorophenoxy-acetic acid	40% e.c.	0.8	Sprayed at 25 days after transplanting.
5	Propanil+2,4-D	—	36% e.c.+80% WP	3.5+0.8	Sprayed at 14 days after transplanting.
6	2,4-P (Na)	2,4-dichlorophenoxyacetic acid	80% WP	0.8	Sprayed at 25 days after transplanting.
7	Swep	3,4-dichlorocarbamilate	80% WP	5	Sprayed at 14 days after transplanting.
8	Swep+MCPA	—	80% WP+40% e.c.	4+0.5	Sprayed at 14 days after transplanting.
9	Simetryne	2,4-bis (ethylamino)-6-methylmerocapto-s-triazine	50% WP	0.5	Broadcast with soil at 10 days after transplanting.
10	Ametryne	2-methylmercapto-4-ethylamino-6-isopropylamino-s-triazine	50% WP	0.5	Broadcast with soil at 10 days after transplanting.
11	Hydram	Ethyl-l-hexamethyl-ineimine carbothiolate	72% e.c.	5.0	Sprayed at 14 days after transplanting.
12	MCPCA	2-methyl-4-chlorophenoxy-aceto-orthochloroaniline	2.5% G	3.0	Broadcast at 10 days after transplanting.
13	DBN	2,6-dichlorobenzoinitrile	50% WP	2.0	Sprayed at 10 days after transplanting.
14	Weedy Check	—	—	—	none.
15	Weeded Check	—	—	—	Handweeded to maintain weed-free condition.

Table 2. Climatic data of the Station during the period of hebicides treatment

Five-day Period	Rainfall amount (mm)	Number of rainy days	Number of sunshine (hours)	Mean relative humidity (%)	Temperature (°C)		
					Minimum	Maximum	Mean
July. 28–Aug. 1	3.5	1	19.9	66.2	24.1	32.5	28.4
Aug. 2– 6	16.7	3	12.1	65.6	24.4	32.8	28.6
Aug. 7–11	35.6	3	8.6	66.0	25.0	32.5	28.7
Aug. 12–16	71.5	4	12.8	71.8	23.4	32.4	27.9
Aug. 17–21	104.6	5	23.2	68.6	24.4	32.1	28.3
Aug. 22–26	88.5	3	22.9	69.6	24.4	32.4	28.4
Aug. 27–31	118.0	5	24.8	72.6	23.5	31.7	27.6
Sept. 1– 5	57.4	3	22.4	70.6	24.7	32.0	28.3
Sept. 6–10	57.9	4	29.2	70.6	24.6	32.4	28.5

of clean paddy rice at 14 percent moisture content was also taken for each treatment from each replication. The data thus collected were subjected to analysis of variance and means were compared by Duncan's multiple range test. Square root, and logarithmic transformations were made for the data of weed counts, and weed weight respectively, before making the analysis. For the data of cover estimates, weed control, and toxicity to rice, the arcsin transformation was made.

RESULTS AND DISCUSSION

The Infestation of Weeds.

The infestation of weeds in the experimental plots as expressed by weed counts and cover estimates made before the application of chemicals are given in Table 3.

Table 3 presented a general picture of weed infestation in the experimental plots before the application of herbicides. Although differences among treatments were quite large in each of the three weed classes in both measurements, the results did indicate that broadleaves predominated over the other two, grasses and sedges in the experimental plots. The broadleaves were mostly aquatic, namely, *Lemma pancicostata*, *Spirerdera polyrhiza* and *Masilea quadrifolia*, while *Monochoria vaginalis* and other broadleaves constituted only a small fraction of this group. The grasses included *Echinochloa* spp., *Leptochloa chinensis* and *Paspalum scrobiculatum*, the latter being mostly the remnants of the previous crop. *Cyperus iria*, *Fimbristylis miliaceae* and *Kyllingia brevifolia* were the predominant sedges of the experimental plots. It should be pointed out here that the plots continuously flooded with deep water since transplanting and the germination of weed seeds broadcasted before transplanting was rather poor. As a result of continuous flooding, the surface of plots were mostly covered with broadleaved aquatics, as indicated in Table 3. However, changes in weed populations did occur after these measurements especially in grasses and sedges which increased both in numbers and coverage.

Table 3. Weed counts and cover estimates based on 0.1 m² subplots

Code No.	Treatment	Weed counts				Cover estimates (%)			
		Grasses	Broad-leaves	sedges	Total	Grasses	Broad-leaves	sedges	Total
1	PCP-Na	1.2	126.2	0.7	128.1	2.4	49.0	0.3	51.7
2	Propanil	3.7	197.3	18.1	219.1	5.0	56.2	7.0	68.2
3	Propanil+MCPA	1.1	194.7	10.7	206.5	2.8	70.0	2.5	75.3
4	MCPA	4.2	323.0	22.9	350.1	4.8	78.2	9.6	92.6
5	Propanil+2,4-D	7.4	200.4	9.5	217.3	8.4	60.4	2.6	71.4
6	2,4-D	6.1	385.5	14.6	406.2	5.9	87.4	5.2	98.5
7	Swep	2.1	196.4	8.1	206.6	1.5	65.0	3.9	70.4
8	Swep+MCPA	1.6	150.0	15.6	167.2	2.4	44.1	8.6	55.1
9	Simetryne	1.1	162.6	3.0	166.7	0.3	45.9	1.9	48.1
10	Ametryne	3.3	125.1	20.9	149.3	3.1	37.9	6.4	47.4
11	Hydram	0.4	319.8	9.2	329.4	0.9	86.8	2.1	89.8
12	MCPCA	0.7	164.6	5.6	170.9	0.3	38.8	1.2	40.3
13	DBN	3.9	177.0	4.1	185.0	1.5	44.0	2.2	47.7
14	Weedy Check	3.6	231.3	8.6	243.5	0.2	59.5	4.4	64.1
15	Weeded Check	0.5	114.8	6.3	121.6	0.5	39.6	1.7	41.8
	Mean	2.7	204.6	10.5	217.8	2.7	57.5	4.0	64.2
	F value	1.06	1.52	1.47	1.92	1.47	3.03**	1.31	5.31**
	LSD 1%	—	—	—	—	—	15.4	—	15.6

** F value significant at 1% level.

The Evaluation of Weed Control.

Several methods were used to measure weed control and its effect on rice plant for each treatment and the results obtained are summarized in Table 4.

From weed counts and cover estimates, it was revealed that good weed controls were obtained in the treatments of Ametryne, Simetryne, PCP-Na, Swep+MCPA and DBN, while Hydram, 2, 4-D and MCPA gave poor control of weeds. Since the plots were occupied mostly by broadleaved aquatics at the early stage of growth of rice plants, the treatments which could kill these aquatics eventually resulted in good weed controls. An efficient control of aquatic broadleaves by PCP, even at a low concentration (0.1%) was also reported by Yui and Yamamoto (1955). The differences among three classes of weeds, compared separately or in total, were highly significant in both measurements among different treatments, except for grasses in weed counts and sedges in cover estimates, where they failed to reach the level of significance.

Weed control estimates were, in general, consistent with the previous two measurements, weed counts and cover estimates. Ametryne and Simetryne gave nearly 80 percent weed control of weeded check, while PCP-Na, Swep+MCPA and DBN resulted in about 60 perecent weed control, An average of 60% weed control by PCP was also reported by Yui and Yamamoto (1955). MCPCA and Hydram

Table 4. Effects of herbicides on weeds and rice plants

Code No.	Treatment	Weed counts (0.1 m²)				Cover estimates (% in 0.1 m²)				Weed control (%)				Toxicity to rice plant (%)	Dry weed weight (g/plot)			
		Grasses	Broad-leaves	Sedges	Total	Grasses	Broad-leaves	Sedges	Total	Grasses	Broad-leaves	Sedges	Average		Grasses	Broad-leaves	Sedges	Total
1	PCP-Na	2.2	19.3	1.8	23.3	7.3	13.8	0.4	21.5	37.3	52.1	82.0	57.0	19.9	990.0	188.0	0.5	1178.5
2	Propanil	2.5	212.2	3.5	218.2	3.6	57.7	2.4	63.7	33.9	36.7	63.7	44.3	0.3	763.7	110.5	7.8	882.1
3	Propanil+ MCPA	0	247.7	0.4	248.1	0	65.4	0	65.4	49.1	51.7	77.9	58.6	0.3	268.8	79.3	2.0	350.1
4	MCPA	4.6	560.7	0.5	565.8	13.7	78.8	0.2	92.7	32.2	52.8	75.9	52.1	12.2	717.5	77.5	0	795.0
5	Propanil+ 2,4-D	3.2	219.2	1.6	224.0	4.4	54.9	0.7	60.0	40.5	49.9	74.3	54.3	1.3	866.3	77.8	2.3	946.4
6	2,4-D	3.2	800.5	4.1	807.8	7.6	89.9	1.3	98.8	32.7	47.2	72.3	49.6	7.7	1043.8	52.8	0.3	1096.9
7	Swep	3.0	95.2	6.2	104.4	2.8	31.2	2.4	36.4	36.1	52.0	79.2	56.1	1.5	681.3	35.8	1.8	718.9
8	Swep+MCPA	3.0	21.6	3.0	27.6	2.6	6.3	0.7	9.6	42.5	69.8	84.4	65.3	0.3	855.0	43.3	0.5	898.8
9	Simetryne	1.9	0.4	1.3	3.6	0.7	0.1	0.6	1.4	60.7	83.6	90.8	78.3	13.6	473.8	44.5	2.5	520.8
10	Ametryne	2.0	0.2	0	2.2	0.5	0	0	0.5	59.9	81.6	95.3	79.1	48.6	1092.5	320.8	9.5	1422.8
11	Hydram	0.4	683.4	3.4	687.2	0.5	97.3	1.3	99.1	68.5	37.1	79.6	59.2	2.9	151.3	39.8	0.3	191.4
12	MCPCA	4.6	202.9	0.7	208.2	5.7	44.0	0.1	49.8	51.8	55.1	81.7	62.3	12.0	650.0	89.8	1.5	741.3
13	DBN	3.5	98.2	0	101.7	2.0	27.2	0	29.2	45.8	52.2	76.4	58.1	12.8	741.3	74.3	1.0	816.6
14	Weedy check	1.6	445.9	9.2	456.7	1.6	92.7	2.6	96.9	0	0	0	0	0	1132.3	165.0	101.8	1399.1
15	Weeded check	0	0	0	0	0	0	0	0	100	100	100	100	0	9.8	4.8	1.0	15.6
	Mean	2.4	240.4	2.4	245.2	3.5	44.0	0.9	48.4	46.1	54.8	75.6	58.3	8.8	695.2	93.6	8.2	798.3
	F value	1.19	10.21**	2.07	10.18**	2.57**	12,57**	1.73	13.20**	25.88**	60.91**	13.96**	35.87**	21.70**	9.29**	3.09**	5.09**	9.31**
	L.S.D. 5%	—	66.9	0.72	64.4	3.6	13.9	—	16.4	3.1	1.4	6.4	2.2	1.7	3.5	5.0	3.7	3.1
	L.S.D. 1%	—	120.7	—	116.1	6.4	24.0	—	28.1	5.6	2.4	11.2	4.0	3.0	5.3	8.6	5.7	4.5

* F value significant at 5 % level.

** F value singificant at 1 % level.

which were poor weed killers when measured by weed counts and cover estimates, appeared to have substantial control of weeds by the weed control ratings. Since floating broadleaves constituted most of the weed populations of experimental plots, the results clearly indicated that good weed control of MCPCA and Hydram could de attributable to more effective control of both grasses and sedges.

2, 4-D and MCPA gave poor control of weed which was in consistent with the two previous measurements. The poor weed control of 2, 4-D and MCPA was due partly to the ineffectiveness of these two chemicals to kill floating broadleaves and partly to the fact that grasses were too large at the time of treatment to permit a complete kill. A similar result was also reported by Smith (1960). Young (1962) found in his experiment that aquatic broadleave weed, *Masilea quadrifolia*, was not killed by 2, 4-D, even though complete kill of *Monochoria vaginalis* was observed. The similar situation also prevailed in this experiment. In general, MCPA controlled weeds better than 2, 4-D.

It is of particular interest to note that Propanil appeared to be the poorest weed killers of all herbicides tried in this experiment. Smith (1961) reported that good control of barnyardgrass was obtained by applying Propanil in the first- to third leaf stages of growth. Experiments conducted by a number of local experiment stations generally came up to the results similar to that of Smith (1961). The results of The International Rice Research Institute (1963) revealed that Propanil gave good control of broadleaves and sedges. However, Propanil was also found to be unable to control one of the aquatic broadleave weeds, *Marsilea quadrifolia*, and some grasses of *Leptochloa* and *Paspalum* species, especially old remnants of them (Chang, 1961). Since Propanil was applied at the proper stage of growth, i. e. 2 to 3 leaf stage, and special attention was also paid for the water managemant, the poor performance of Propanil in this experiment appeared to be due largely to the poor control of this chemical on most of aquatic weeds and some grasses, the weeds unfortunately were the major problem. The chemical was sprayed with a sprayer without a pressure regurator, and it was doubtful that a good coverage was ever attained. Propanil is a contact herbicide and good coverage is a prerequisite to good weed control. Therefore, poor weed control witnessed in this experiment for Propanil may also be related to the incomplete contact of the chemical.

Differnces of weed control among treatments were highly significant in three classes of weeds and in average.

Phytotoxicity of herbicides to rice plants was manifested in several ways and some of them were qualitative in nature and difficult to be expressed quantitatively. Ametryne, PCP, Simetryne, and DBN, which were among the best weed killers, happened to be also the most toxic herbicides to rice plants. The injury of these chemicals was manifested by burning of the rice seedlings. Among them, Ametryne appeared to be the most toxic one and the leaf burn caused by this chemical ultimately ended in complete kill of rice plants. As a result, the stand of rice was reduced greatly. However, the injury caused by the other three did not result in

death and it was found to recover within 7 to 10 days. The phytotoxicity of MCPCA and 2,4-D was manifested mostly in qualitative manner, such as stunting growth, yellowish leaves and reduction of tillers. Very slight or even no toxicity was detected for Propanil, Swep, and Hydram, as already observed on Propanil by Smith (1961) and on Swep by Hudgins (1964). The difference in phytotoxicity to rice greatly exceeded the 1% level of probability.

So far, no different response of rice varieties to the toxicity of herbicides ever tried was detected and rice varieties were found to respond similarly to 2,4-D (Smith, 1958). However, different varietal response to herbicides was observed in other small grain crops. Price and Klingman (1958) reported that wheat and oat varieties responded differently to varying treatments of 2,4-D. Hodgson *et al.* (1964) also detected differential response of certain barley and wheat varieties to seven herbicides namely, 2,4-D, MCPA, Dicanba, Barban, G 3436, Propanil and DMPA. Resistance to an agricultural chemical in barley was found by Wiebe and Hayes (1960) to be genetically controlled by a single major recessive gene. Since some of best weed killers in this experiment were very toxic to rice plants, it is reasonable to suppose that a much better job could be done if the rice varieties were genetically resistant to the herbicides applied. At the same time, solutions for the reduction of phytotoxicity can also be approached from further tests in formulation of herbicides, active rate applied per unit area, time of application, and many others.

The measurment of dry weed weight indicated that grasses gave the majority of the final product of weeds, while broadleaves and sedges comprised only small portions of it. The data reflected a change in the importance of weed infestation, from broadleaves in the early stage to the grasses at the late stage of rice growth. It was observed that aquatic weeds often died when rice was approaching maturing stage, while grasses, especially barnyardgrass which was so inconspicuous at the early stage of rice, grew vigorously with the growth of rice and they eventually dominated the weed population at late tillering stage of rice and provided severe competition for rice. As a result, herbicides which gave good control on grasses, such as Hydram and Simetryne resulted in light weight of dried weeds. Ametryne actually gave good weed control on all classes of weeds, but it also reduced the stand of rice which provided an open space for the growth of weeds, especially grasses and *Monochoria vaginalis*. Conseqnently, Ametryne produced higher yield of weeds in both grasses and broadleaves. PCP, the second heavy producer of weeds, also gave good control of weeds at the first application but some weeds, which were not completed killed, eventually recovered and were too large to be killed at the second application. Since weed competiton with rice was reported to be most serious during the first 30 days after emergence of weeds (Show and Danielson, 1961), the increase in rice yield treated with PCP may be attributable to the good weed control obtained at the first application. 2,4-D, Porpanil and MCPA which gave poor weed control by the other measurements, also produced higher

yields of weeds. It should be noted, however, that weedy check produced as much weeds as Ametryne and weeded check left only a trace of weeds. The differences in dry weight of weeds were significant at 1% level of probability.

Among methods used in this experiment for evaluation of weed control, only the measurement of dry weed weight is free from artificial errors associated with investigators. Therefore, it may present the most accurate information on the effect of herbicides. However, it should take into account the change of weed population during the whole period of rice growth if weed control of herbicides is to be evaluated correctly. The other measurements are more or less arbitrary and subject to variabilities associated with time of rating and individual investigators involved. In this experiment, it was tried to minimize the variability of these measurements as much as possible.

Effects of Herbicides on Some Agronomic Characters of Rice.

In order to know to what extent rice plants are affected by herbicides, some important agronomic characters were measured. A summary of the data and F values computed on these characters are presented in Table 5.

It was indicated that Ametryne significantly delayed the date of heading. The

Table 5. Effects of herbicides on some agronomic characters of rice plants

Code No.	Treatment	Heading date (days)	Plant height		Number of tillers per hill	Panicle	
			40 days (cm)	Full ripe (cm)		weight (g)	length (cm)
1	PCP-Na	58	87.1	111.8	9.7	4.5	23.9
2	Propanil	57	91.1	113.2	10.0	4.3	25.2
3	Propanil+MCPA	57	89.2	113.6	8.7	4.9	25.1
4	MCPA	56	81.5	115.5	8.1	4.8	25.1
5	Propanil+2,4-D	58	91.2	115.2	9.3	4.8	25.1
6	2,4-D	57	84.0	114.5	9.0	4.8	25.3
7	Swep	57	95.6	117.7	10.9	4.5	25.1
8	Swep+MCPA	57	91.5	117.0	10.6	4.9	24.7
9	Simetryne	57	88.9	113.9	9.7	5.4	25.2
10	Ametryne	60	84.9	111.1	9.7	5.4	24.9
11	Hydram	58	91.5	112.9	9.9	4.5	24.8
12	MCPCA	58	85.2	114.7	7.4	5.2	25.3
13	DBN	58	88.2	112.2	9.5	4.3	24.6
14	Weedy check	56	94.3	113.0	9.4	4.3	24.6
15	Weeded Check	58	93.0	114.5	10.9	4.4	24.7
	Mean	57	89.2	114.1	9.5	4.7	24.9
	F value	3.67**	7.27**	1.48	4.33**	2.25*	0.98
	L.S.D. 5%	1.2	4.3	—	1.3	0.7	—
	L.S.D. 1%	1.6	5.7	—	1.8	—	—

* Difference significant at the 5% level.
** Difference significant at the 1% level.

severe injury caused by this chemical apparently inhibited the early growth of rice and eventually resulted in later maturity. The plots heavily infested with weeds such as those of weedy check, MCPA and 2, 4-D, headed significantly earlier than others, indicating that keen competition with weeds could hasten the maturity of rice.

Plant height measured at 40 days after transplanting were highly significant among treatments, reflecting the influence of phytotoxicity of herbicides. When the plant height was again measured at maturity, no significant difference was evident, showing that the injury had fully recovered.

Phytotoxicity of herbicides was also manifested in the reduction of tillers. As indicated by the result, MCPCA produced least tillers, suggesting that tillering ability of rice was severely inhibited by this particular chemical. The vegetative growth of weeds treated with MCPCA was also observed to be poor, indicating that good weed control of MCPCA may be due primarily to its suppressive effect on the growth of weeds. In general, weeds infestation reduced the number of tillers. The difference in number of tillers per hill was significant at 1% level of probability.

Rice plants with less tillers as in the plots of MCPCA generally produced heavier panicle. The difference in panicle weight was significant at the 5% level of probability. Panicle length was not significantly affected by the treatments.

Effects of Herbicides on Grain Yield and Components of Yields.

Since the ultimate interest of conducting a herbicide experiment is to find out the effect of herbicides on the actual yield of rice, the data on grain yield and its components were taken. The results are given in Table 6.

Growing conditions during the whole period of growth were good and insect pests as well as diseases were also well under control. The grain yield of weeded check was typical for Chianung 242 obtained at Chiayi area on this crop season. DBN produced the highest yield while Ametryne the lowest. The difference in yield among treatments greatly exceeded the 1% level of significance. Although grain yield was not significantly different from weeded check except for weedy check and Ametryne, the increase of yield by several herbicides or mixtures of herbicides was quite great. DBN increased 563 kg per hectare or 12.0% when compared with weeded check. When compared with weedy check, DBN produced 1,320 kg per hectare or 33.6% more grain yield, a difference greatly exceeding the 1% level of probability. Non-weeded check reduced 757 kg per hectare or 19.3% of grain yield in comparison with weeded check, which was weeded by hands as commonly practiced by farmers in Taiwan. The degree of reduction in yield caused by weed competition was lower than 37.5% as reported by Shaw and Danielson (1961), but it was quite similar to the average estimated loss of 20-40% in Japan and 14% in the United states.

From the analysis of yield components, it was revealed that both number of

Table 6. Effects of herbicides on grain yield

Code No.	Treatment	Grain yield (kg/ha)	Components of yield		
			Number of panicles per hill	Number of grains per panicle	Weight of 1,000 grains (g)
1	PCP-Na	4,828 a-b***	8.2	162.8	30.4
2	Propanil	4.435 b-d	9.0	151.3	29.7
3	Propanil+MCPA	4,322 b-d	8.3	181.7	28.9
4	MCPA	4,665 a-c	7.8	162.8	30.0
5	Propanil+2,4-D	4,658 a-c	8.2	177.1	29.3
6	2,4-D	4,215 b-d	8.3	170.4	28.6
7	Swep	4,775 a-b	8.5	163.9	30.0
8	Swep+MCPA	4,694 a-b	9.0	179.7	30.5
9	Simetryne	4,739 a-b	8.5	188.0	29.5
10	Ametryne	3,849 d	8.4	192.4	30.3
11	Hydram	4,701 a-b	9.3	158.9	30.0
12	MCPCA	4,920 a-b	7.1	192.5	29.8
13	DBN	5,253 a	9.2	163.9	29.2
14	Weedy check	3,933 c-d	8.6	153.3	30.0
15	Weeded check	4,690 a-b	9.0	161.3	28.5
	Mean	4,578	8.5	170.7	29.6
	F valne	3.94**	2.48*	4.06**	1.24
	L.S.D. 5%	734	1.05	19.37	—
	L.S.D. 1%	983	—	25.92	—

* Difference significant at the 5% level.
** Difference significant at the 1% level.
*** Letters with a dash between are inclusive for the range, grain yields with letters in common are not significantly different from each other at the 5% level.

panicles per hill and number of grains per panicle were significantly affected by the treatments of herbicides and weed competition while weight of 1,000 grains was not significantly affected. Apparently either number of panicles or number of grains, had contributed to the increase of yields. The reduction in number of panicles was not so serious as that of number of grains in weedy check, indicating that the latter was more sensitive to weed competition than the former. It was also indicated that low yield in the plots treated with Ametryne may be attributable primarily to the reduction of rice stand, since yield components gave more than the average values.

The treatmets of DBN, MCPCA, PCP-Na, Swep, Simetryne and Hydram showed a strong trend toward yield increase, suggesting that adequate weed control may be available with these chemicals. A substantial increase in yield by DBN and vigorous growth of rice plants during the early growing stage treated with Swep indicating a stimulatory effect from these chemicals. If the phytotoxicity of PCP-Na, Simetryne and Ametryne can be reduced by readjusting time of application, reducing active rate to be used, applied in granules or by other means, these

chemicals may appear promising as paddy herbicides. However, these results are based on only one season's testing and more thorough testing is necessary.

Propanil which has been intensively studied in Taiwan and elsewhere, may find its application quite difficult in the second crop of rice when monsoon climate prevails, since it requires at least 8 to 12 hours after treatment for the absorption by weeds. Furthermore, at certain places where facilities for good irrigation and drainage are not available, water management will also be a problem for Propanil. The spraying of insecticides will become more or less inflexible by the application of propanil.

Under present conditions, more herbicides in granular formulation should be tried in Taiwan, since granules can be easily spread by hands and do not require an expensive spraying equipment. At the same time, the phytotoxicity of herbicides to rice can also be reduced. It is also commonly known that several species of weeds, varying in susceptibility to herbicides, are usually grown in paddy field. It is, therefore, suggested that more mixtures of herbicides which differ in their effectiveness in controlling various weed spectrums, should be evaluated.

It was also shown that the tillage which has been an important standard cultural practice of rice in Taiwan, did not contribute greatly, as generally regarded it would be, to the vegetative growth and grain yield of rice, indicating that this time consuming and laborious practice may be unnecessary, as long as paddy fields are maintained free from weeds.

Time-to-weed was estimated to be about 10 minutes per plot per hand weeding for weeded check under the conditions of this experiment. It is equivalent to about 133 man-hours or 17 work-days per hectare. Based on this measurement, a total of 399 man-hours or 50 work-days will be needed with an estimated cost of NT$1,000 or US$25 per hectare if good control is to be obtained by hands. Meanwhile, current price figures indicate that the costs of commercially available herbicides are estimated to range from NT$64 or US$1.6 per hectare for MCPA and 2, 4-D, NT$600 or US$15 per hectare for PCP to NT$1,120 or US$28 per hectare for Propanil with methods of application indicated in this experiment. Chemical weed control is, therefore, not necessarily expensive nor impractical. At the present time, a solution of weed problems seems to be best approached by substituting one or two hand weedings by one application of certain herbicides. In view of the rapid progress in industrial development and possible reduction in the price of herbicides, it is believed that the future prospect for chemical weed control to become an integral practice of rice culture in Taiwan seems bright.

SUMMARY

Field investigation was made on the second crop (wet season) of 1964 at Chiayi Agricultural Experiment Station to evaluate the effectiveness of 13 herbicides and herbicide mixturers together with weedy and weeded checks for controlling weeds

in rice. A total of 15 treatments were arranged in randomized complete blocks with four replications. The effects of herbicide treatments on rice were evaluated by weed counts, cover estimates, weed control ratings, phytotoxicity estimates, weed weight, agronomic characters and grain yield. Some findings of this investigation may be summarized as follows:

Ametryne and Simetryne gave best control of weeds, particularly of aquatic floating broadleaves which were apparently not killed by other chemicals. When weeds, especially grasses were rather large at time of treatment, they were not controlled by PCP-Na, MCPA and 2, 4-D. Propanil gave poor control of weeds under the conditions of this experiment.

Rice was injured severely by Ametryne, PCP-Na and Simetryne. MCPCA was also found to have certain inhibitory effects on the growth of rice. Propanil and Swep were not toxic to rice under flooded condition.

Broadleaved weeds, especially those of aquatics dominated the weed population of the experimental plots at the early stage of rice growth, but their position was apparently taken over by grasses at the late stage. The change in weed population was clearly reflected in weed weight which was primarily contributed by grasses. Sedges were not an important problem.

Weeds hastened the heading of rice while chemical injury delayed it. Plant height and tillering ability of rice was significantly reduced at the early stage of growth. Panicle length and grain weight were not affected by herbicide treatments but weeds seemed to reduce number of grains per panicle.

DBN, MCPCA, PCP-Na, Swep, Simetryne, Hydram and a mixture of Swep+ MCPA produced more grain yields than weeded check. DBN yielded 563 kg or 12.0% more than weeded check and 1,320 kg or 33.6% more than weedy check, the latter being significant at 1% level. Weedy check reduced grain yield by 757 kg or 19.3%, a difference exceeding the 5% level of probability, when compared with weeded check, indicating a serious loss of yield by weed competition. Ametryne gave the lowest yield due to the reduction of stands caused by its toxicity to rice.

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幾種水田新殺草劑之治草效果

張　萬　來

摘　要

嘉義農業試驗分所與國際稻米研究所合作，於民國53年第二期作舉辦水田殺草劑治草試驗，應用十三種不同配合之殺草劑，從事水田治草效果觀察，茲將初步所得結果，簡述於後：

Ametryne 與 Simetryne 殺草效果最佳，尤對紫背浮萍，青萍及田字草等水生濶葉雜草，具有特效。惟一般殺草劑對大株雜草效果較差，Propanil 在本試驗之治草效果最差。

Ametryne，PCP 與 Simetryne 對水稻毒害較强，MCPCA 有抑制水稻發育現象，僅 Propanil 和 Swep 對水稻未有毒害作用。

水稻生育初期，稻田雜草大都爲水生濶葉草，中、後期則以稗草類之雜草爲最多，水生濶葉草在水稻生育後期逐漸自滅，故收穫前所得雜草乾重以稗草所佔比例最大，而三稜葱草，鴨舌草及水蓼蚜等所佔比例較少。

雜草叢生可促進水稻抽穗，但對每穗粒數似有減少之趨勢，水稻受殺草劑强性毒害則延遲抽穗。殺草劑可抑制水稻生育早期之株高及分蘖，但不影響穗長，千粒重。

DBN, MCPCA, PCP, Swep, Simetryne, Hydram 以及 Swep+MCPA 處理區稻谷產量超過慣行除草區。DBN 處理區每公頃產量較慣行除草區多出563公斤（12%）比不除草區高1,320公斤（34%），後者差異達 1% 顯著值，不除草處理比慣行除草者減產757公斤達 19%，其差異遠超5%顯著水準，由此概見水田雜草爲害，使稻谷減產之一斑。Ametryne 因具有强性毒害，致使部份水稻被害，呈顯缺株，其產量乃受影響。